Development of the Aerosonde Robotic Aircraft

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LONG-TERM GOALS

Our long-term goals are to develop improved understanding and prediction of the atmosphere, with particular emphasis on tropical cyclones. Our work encompasses research into basic processes, observing system development and related field programs, and development of forecast and impacts reduction systems.

OBJECTIVES

To continue development of the Aerosonde Robotic Aircraft in support of Navy requirements, by:

1. Continued work to increase robustness and operational flexibility of the aircraft;
2. Development of new instrumentation and capacity; and,
3. Undertaking related field trials and system testing.

APPROACH

The Aerosonde robotic aircraft has been developed to provide a flexible and low-cost observing platform for a wide variety of needs, most notably in the field of meteorology. Our initial development phase produced the Mark 1 Aerosonde by a combination of engineering development and extensive field testing. This approach has proven to be quite successful and is being maintained in the continued development of the Aerosonde by the following sequence: specification of user and operational requirements; engineering design and specification; detailed costing and resource requirements; engineering development; test and evaluation; full documentation of the final system; operational acceptance.

This continuing process has now identified a development sequence from the Mark 1 Aerosonde to an envisaged mutifunctional Mark 4 aircraft. Details can be found at www.aerosonde.com.

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **30 SEP 1999**	2. REPORT TYPE	3. DATES COVERED **00-00-1999 to 00-00-1999**
4. TITLE AND SUBTITLE **Development of the Aerosonde Robotic Aircraft**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Bureau of Meteorology Research Centre,PO Box 1289K,Melbourne, Vic 3001, Australia,**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S)
		11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

WORK COMPLETED

The Mark 2 Aerosonde robotic aircraft made its first flights in September. It represents an evolutionary move from the Mark 1, with improved reliability, an upgraded 26 cc engine and substantial improvements to onboard software and avionics systems. Its specifications are in Table 1.

Table 1. Aerosonde Robotic Aircraft^{TM} Mark 2 Specifications

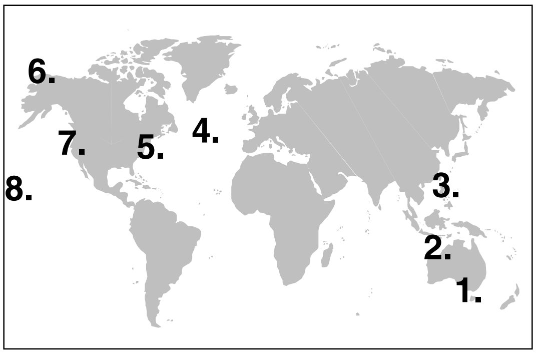
Weight, wing span	13-14 kg, 2.9 m
Engine	26 cc, Avgas 100LL, 1kw normally aspirated with 50 w generator
Navigation	GPS, DGPS, automatic storm/front tracking
Aerosonde Robotic Aircraft^{TM} Operation	
Staff for Launch and Recovery	3: Controller, Engineer, Pilot/Maintenance
Staff for Flight Operations	1 Person for 2-3 aircraft
Ground Equipment	Proprietary Staging Box, Personal Computer GPS Antenna,
Flight	Fully autonomous, under Base Command
Takeoff, Landing	Car roof rack, belly, Autonomous or with pilot
Ground & air communications	UHF to Aerosonde, VHF to FSU and other aircraft, Dial modem link to remote command
Aerosonde Robotic Aircraft^{TM} Performance	
Speed, Climb	18 – 32 ms^{-1}, Climb 2.5 ms^{-1}
Range, Endurance	>3000 km , >30 Hrs
Altitude Range	100 m – >5000 m (intermediate weight)
Mean Time Between Failures	200 h
Payload	Maximum 2 kg
Aerosonde Robotic Aircraft^{TM} Standard Instrumentation	
Temperature, Pressure, Humidity, Wind	3 Vaisala RSS901 Sondes <0.1^{o}C, <0.2 hPa, <2% Humidity, Proprietary wind <0.5 ms^{-1}

We accomplished over 200 flight hours during the year, combining continued field testing with operations in: Cape Grim, Tasmania for the SOAPEX; North Carolina for the Navy, Barrow; Alaska for the DOE; Hawaii for the National Weather Service; and Dayton, Ohio for the USAF. In addition, the Taiwan Aerosonde group flew two sets of missions in southern Taiwan.

System work included an assessment of the use of the three main LEO communications providers, extensive checking and debugging of the flight and ground-station software, a comprehensive documentation of the operational system, and preparation of an operator's manual.

RESULTS

Since 1995 the Aerosonde has participated in a wide range of field programs, as indicated in Fig.1. These programs have provided the extensive testing and fault finding that has taken the aircraft from a rough prototype to the sophisticated Mark 2 aircraft that enters operations in 2000.



1. Development and Test Site (1995-Present); Demonstration Flight, Canberra (1998); Field Mission, SOAPEX (1998).

2. Field Programs: MCTEX (1995), Broome (1997), Port Hedland (1998).

3. SCSMEX Field Program (1998), Demonstration Flight, Taiwan (1998).

4. Trans-Atlantic Flight (1998).

5. Trial for US Navy (1999), Demonstration at WP AFB (1999)
6. Arctic Field Program (1999)
7. Field and Test Programs (1995-1999)
8 Trial for US National Weather Service (1999)

Figure 1. Areas of operation for the Aerosonde robotic aircraft since 1995.

Major achievements during this period were the successful achievement of all milestones in a full operational trial conducted by the Australian Bureau of Meteorology in January 1998 (#2 in Fig. 1) and the first crossing of the North Atlantic by a UAV in August 1998 (#4).

Operations for the Navy in North Carolina, February 1999: We conducted a demonstration of Aerosonde capacity in support of an exercise by the Second Fleet. The goals were to demonstrate that Aerosondes can provide meteorological data in support of fleet operations.

Following our well-proven method of operation, launch and recovery occurred at Atlantic Field (Fig.2). All other operations were under command control of a group at the NAVMETOC Center at Norfolk Naval Station. Communications were via UHF radio and telephone lines. This enabled the Fleet meteorologists to set goals and also ensured rapid transmittal of data through the military net.

Severe icing detected during the mission on Wednesday 24th February: This mission clearly demonstrated the capacity of Aerosondes to obtain observations of mesoscale features in the tasking region. This is illustrated by the data for one flight in Fig. 3.

The flight proceeded along the transect shown in Fig. 1, with a moderate northwesterly flow of 5-10 ms^{-1} and, relatively warm temperatures of 1-2^{o}C. Once inside the operations region (circle in Fig. 2), a descent to 750 ft was initiated to commence the sounding cycle. This brought the aircraft into wet, cold air trapped against the coast and ranges. The transition was very sharp being ~ 50 m in the vertical. Freezing temperatures and 100 % humidity rapidly developed icing problems and the aircraft was ordered to ascend.

Figure 2. The Aerosonde operations are, launch/recovery site, and command center at Norfolk.

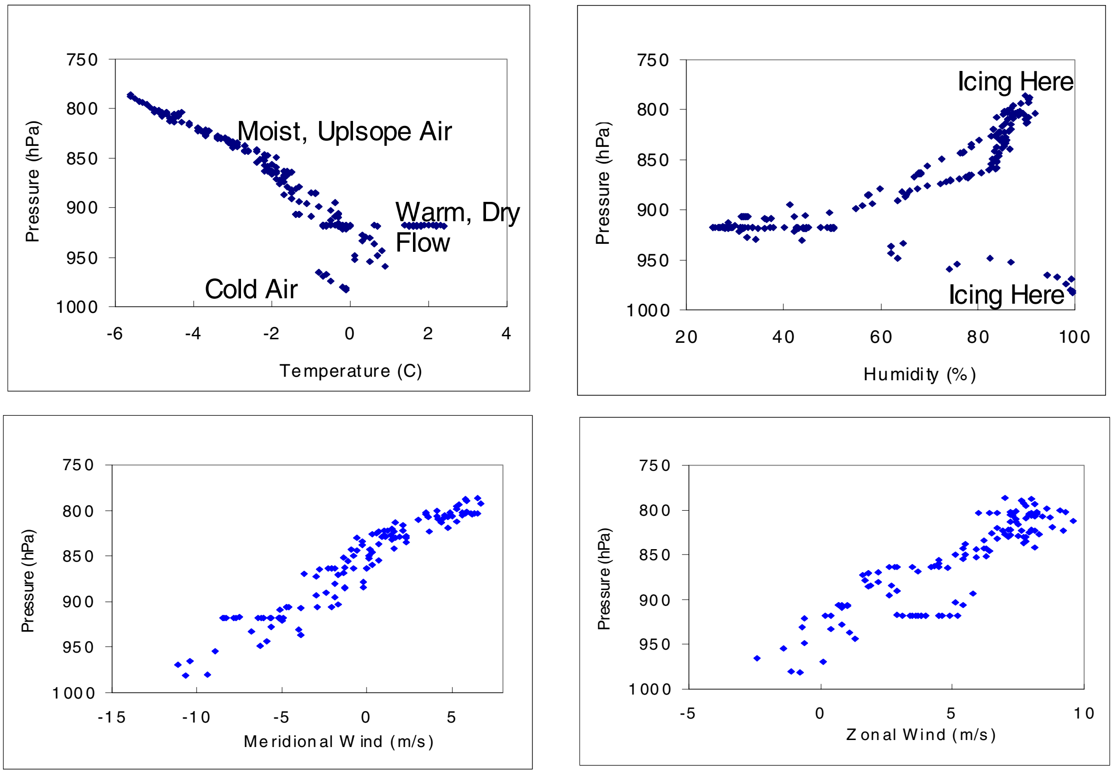


Figure 3. Soundings of temperature, humidity, and meridional and zonal wind components obtained by the Aerosonde on 24 February 1999.

After transiting the dry/warm zone of northwesterly flow, the Aerosonde ascended into a region of moist upslope in southwesterly flow. Radar imagery for the time showed a marked mesoscale band of precipitation moving through the region. Above 800 hPa, icing buildup on the airframe caused control problems and a slow descent was commanded to provide high-resolution observations. The Aerosonde returned to base in the relatively warm and dry northwesterly flow.

The lessons learnt for operations were that the region of low-level icing had not been predicted and was only discovered by the Aerosonde flight. The military aircraft missions for that day were rescheduled as a result.

IMPACT/APPLICATIONS

The Aerosonde is opening up a new era in economical aircraft operation, particularly in remote and hazardous areas. As envisaged by Holland et al. (1992) the Aerosonde enables flexible operations in meteorology from routine soundings to observing severe weather and specialized flights into otherwise inaccessible regions. One particularly significant application is for Aerosondes to be deployed as a major component of an adaptive observing strategy. The Aerosonde is also being considered for applications in atmospheric chemistry, biological and environmental surveys, surveillance, and as a secure local over horizon communications relay system.

The potential is emphasized by extensive operations that have already been accomplished and by the widespread endorsement of the Aerosonde by international organisations including the WMO Commission for Atmospheric Sciences, the International Council of Scientific Unions, the Executive Committee for the International Decade for Natural Disaster Reduction, and the ESCAP/WMO Typhoon Committee.

TRANSITIONS

The following transitions have already commenced:

- Move to an operational system, with 6 field programs conducted in 1999 and several at the planning stages in 2000;
- The potential for use of the Aerosonde in Naval operations has been demonstrated and operational plans are being developed;
- Development of specialized instrumentation, including chemical sensors, camera systems, and communications relay capacity.

In addition, the following are under active consideration:

- Establishment of an Aerosonde Global Reconnaissance Facility with the Australian Bureau of Meteorology;
- Establishment of a routine program of reconnaissance in the western North Pacific with Japanese and Taiwanese groups;
- Establishment of an Arctic operations base at Barrow, Alaska with support from the National Science Foundation.

RELATED PROJECTS

- Our tropical cyclone program (ONR N00014-94-1-0493) will be working closely with the Aerosonde project on mutual programs of data collection and research into mesoscale aspects of tropical cyclones.
- The WWRP and USWRP programs on landfalling tropical cyclones, the proposed THORPEX in the North Pacific and the North American Observing System people have expressed interest in invloving Aerosondes in their programs.
- Establishment of an Arctic operations base in collaboration with the NWS and the NSF Arctic Operatipons Group.

REFERENCES

Holland, G.J., T. McGeer and H. Youngren, 1992: Autonomous Aerosondes for economical atmospheric soundings anywhere on the globe. *Bull. Amer. Met. Soc., **73**,* 1987-1998.

PUBLICATIONS

A number of field reports, including data are available form our web site at www.aerosonde.com.

McGeer, T. and G.J. Holland, 1994: Small autonomous aircraft for economic oceanographic observations on a wide scale. *Oceanography*, ***6*** (3).

Holland, G.J., T. McGeer and H. Youngren, 1992: Autonomous Aerosondes for economical atmospheric soundings anywhere on the globe. *Bull. Amer. Met. Soc., **73**,* 1987-1998.